TION OF A 12-YEAR-OLD GLUED-LAMINATED STRINGER BRIDGE WITH NAILED-LAMINATED DECK--DECAY HAZARD ASPECTS

By

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Summary

This project was undertaken jointly by the U.S. Forest Products Laboratory and the Gifford Pinchot National Forest Engineers. Objectives of the project and the major findings include:

The 12-year-old Panther Creek Bridge in southern Washington was inspected thoroughly for the presence of decay in conjunction with complete deck removal and an experimental deck replacement project.

Advanced decay conditions were found commonly in the nailed-laminated decking and in one instance in a main span, glued-laminated stringer. Such decay must be considered as highly significant regarding the probable service life that could have been expected from the bridge if the decay had not been detected. Of greater significance is the fact that this bridge may represent numerous other bridges having comparable designs, exposures, heavy use, and constructed of similar materials and by similar methods.

It was concluded that the early decay infections had resulted from a combination of factors including: (a) The limited effectiveness of the preservative treatment applied without incising; (b) the high frequency of through- and toe-nailing common in nailed-laminated decking, and (c) excessive movement of the decking (in response to heavy loading) that resulted in nail hole enlargement and extensive wetting of interior untreated wood in the various members. Shrinkage of the original decking after installation also contributed to deck looseness.

In rebuilding the bridge deck, three classes of decking were used. These included: (a) Glued-laminated deck slabs, (b) new, kiln-dried, creosote pressure-treated, nailed-laminated decking, and (c) salvaged original decking in a wet condition but also creosote pressure treated and representing old, nailed-laminated decking.

The complete deck was subsequently surfaced with an asphalt mat that was seal-coated as a barrier to further bridge deck or stringer wetting. Subsequent comparisons should include appraisals of the decking for (a) drying rate of the salvaged old decking, (b) moisture changes in the two new forms of decking, and (c) the comparative capacity of the three types of decking to adequately support an asphalt mat on a single-lane, three-stringer bridge.

Proper handling and preservative treatment of bridge elements, along with proper construction techniques, should result in much longer life for many Forest Service bridges.

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CONDITION OF A 12-YEAR-OLD GLUED-LAMINATED STRINGER BRIDGE WITH NAILED-LAMINATED DECK-- DECAY HAZARD ASPECTS[1]

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Background and Purpose of the Project

The Forest Products Laboratory has for some years been cooperating with the Division of Engineering of the Forest Service in an investigation of various aspects of typical wood bridges. One part of this effort involved observation of a number of bridges to determine whether decay-hazardous conditions were present.

After a survey of moisture conditions in the upper laminates of glued-laminated bridge stringers had largely confirmed by late 1966 that a decay-hazardous condition existed in a number of Forest Service bridges, an opportunity was requested to examine representative stringers by actual deck removal and direct inspection. Subsequent observations, including loose nailed-laminated decking on several bridges, and the additional observations of the very limited penetration of preservative in many stringer laminates further pointed to the need for such an examination. Although decay was thought to be present in the untreated, interior portions of the bridge members and particularly the untreated, wet parts of the upper laminates of the glued-laminated stringers, no decay had been detected by probing or by limited boring of either decking or stringer members.

In September 1969, Gifford Pinchot Forest Engineers and the Forest Products Laboratory began a multipurpose cooperative study of the Panther Creek Bridge in Washington. The study covered the following considerations and variables:

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[1] The author wishes to express his appreciation to Engineer Leon B. Boland for his assistance in taking the data during the inspection.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Bridge decking was removed and the decking and stringers were examined to confirm the presence or absence of decay and to relate any decay to suspected sources of moisture. Decking replacement involved the reuse of some of the old decking, of new kiln-dried and pressure-treated decking, and the installation of glued-laminated decking panels.

For an adequate appraisal of the possible factors contributing to the decay hazards and of any decay to be found, it was essential to consider and observe all aspects of the dismantling and rebuilding activity. Particular attention was given to fasteners since excessive looseness of several other nailed-laminated decks had indicated an inadequate number of fasteners, a deficiency in fastener size, or numerous failed fasteners. This deck looseness had effectively prevented the establishment of satisfactory deck seals and was thought to account for additional decay hazard either directly or indirectly.

Emphasis in this report is on the decay-hazard aspects. Because the entry of water to create the decay hazard unquestionably relates to the type of decking, some aspects of both old and new replacement bridge decking are also covered.

The replacement decking is experimental. Observations of the behavior of the bridge should be continued to appraise the effectiveness of the three types of decking in preventing water leakage and thus reducing the decay hazard.

The Panther Creek Bridge

The Panther Creek Bridge near the Hemlock Ranger Station on the Gifford Pinchot National Forest is a typical single-lane Forest Service bridge. It was constructed in 1957 and the total length is 103 feet. The main span and both approach spans are supported by three glued-laminated stringers each. The ends of the bridge are supported on poured-in-place concrete abutments with two comparable piers supporting the adjacent ends of the approach span and the main span stringers. All the approach stringers are the same size, 11 by 24 inches by 25 feet, while the main span stringers are uniformly 11 by 37 inches by 49 feet 9 inches. In all three spans the stringers are set on 5-foot 6-inch centers. The stringers were pressure treated with creosote after laminating but without incising.

The stringers are laterally spaced by welded angle-iron diaphragms bolted to the stringers at their ends, at the midpoint of the approach span stringers, and at one-third intervals of the main span stringers.

The nailed-laminated decking consisted of creosote-pressure treated 2- by 8-inch second-growth Douglas-fir, S2E, and not incised. Each

of 15-foot 6-inch deck boards was nailed through with either 10 or 11 thirtypenny galvanized nails; and in every other laminate six twentypenny toenails attached the deck system to the stringers (two per stringer crossing).

Generally the penetration of preservative treatment in both decking and stringers varied from 1/4 to 5/8 inch into the flat and edge faces, with occasional deeper penetration where sapwood was present.

The Panther Creek Bridge was one of the first bridges to be included in the decay-hazard survey and has been intermittently observed since 1965. Permanently placed moisture probes have consistently shown a number of hazardously high moisture content areas in the upper laminates of the glued-laminated stringers on this bridge.

Throughout the history of this bridge, the deck surface has had steel tread plates in the tread areas. At no time has the deck surface been protected by any other material. The common difficulty experienced with tread plates was in evidence on the Panther Creek Bridge. Some bolts which hold the tread plates in place were sheared away by snowplows so that the ends and sides of some plates were loose. Where the deck plate ends were loosened and bent downward, gouging and mechanical wear into the decking were noted (fig. 1). The gouging exposed untreated wood in some instances.

Maintenance had been neglected on the Panther Creek Bridge as was the case to some degree on many Forest Service bridges inspected in the earlier survey. In addition to the poorly attached tread plates, heavy accumulations of gravel, sand, or dirt had built up on the bridge to depths up to 8 to 10 inches, which in some cases blocked adequate lateral deck drainage under the wheel guards (fig. 2). Such heavy accumulations of soil definitely contribute to the hazardously wet conditions that prevail in the decking and in the upper stringer laminates.

Decking Observations

Removal

The original 12-year-old, nailed-laminated deck was completely removed in the 1969 inspection. Individual laminates were loosened for removal with two heavy spuds (fig. 3). The boards were removed in reverse order from the original installation order, making it possible to observe the decking and deck-nail conditions with minimal distrubance due to the mechanics of the removal process. In no case was evidence observed of nail breakage, either of the through-nailing or toenailing, that was attributable to the deck removal process.

In general, 1/16- to 1/4-inch spaces were found between decking boards and some spaces were as wide as 1/2 inch (fig. 4). These spaces are not entirely attributable to shrinkage since many boards were still at a relatively high moisture content. Part of the spaces result from deck movement and to a somewhat loosely laid original deck. These spaces frequently were partially filled with a mixture of creosote and sandy loam soil. Often such material was firmly compacted and adhering to one or the other of the adjacent pieces of decking (fig. 5), so that even in the wet condition moderate scraping pressure was required to remove it with either a steel spud or a large carpenter's adze (fig. 6). Considering the man-hours required to carefully remove and clean the decking, and the questionable quality of the decking due to incipient decay that may not have been detected and eliminated, it was obvious that reuse of the old decking was not a practical or economical procedure. However, reuse of some of the old decking was a planned part of the experimental redecking project.

Fasteners

Throughout the deck removal procedure, careful observations were made of all deck fasteners. A collection of broken or deformed nails was made and representative examples are shown in figures 7 and 8. Both the through-nails and the toenails were frequently either bent or broken. In numerous cases, the through-nails were broken in two or three pieces, but the pieces usually remained in the boards into which they had been driven. Nails retaining their full length were often reduced in diameter. In some cases, these nails showed long, tapered reductions which appeared to be the result of abrasive wear, of rust, or a combination of these factors. It was not uncommon to observe all galvanizing eliminated from two-thirds of a nail's length. In other cases, nails appeared to have retained their full diameter but simply had been broken near their midpoints, presumably as a result of repeated flexing.

Often the broken ends of such nails were rounded, indicating abrasive action by the sand embedded in the wood as the wood members moved under traffic loading after the nail had broken. In many cases, the nails were rather highly polished, showing no evidence of rust over half of their length. Toenails often showed breaks occurring from a point a half inch below the surface of the stringer up to a point 1/2 inch above the stringer surface. In such cases, the nail end frequently remained firmly implanted in the upper stringer lamination (fig. 9). In other cases, the toenail hole in the top of the stringer was enlarged and the nail had simply moved up and down freely as the deck member moved. Enlargement of the through-nail holes in the decking boards was quite common and in some cases so pronounced that the nails or pieces of nails dropped out of the planks during plank removal.

A few through-nails were very heavily rusted and firmly implanted in wet wood. Such nails were usually found to be broken, with separate nail pieces isolated in individual boards, so that no stress was imposed by deck deflections to cause them to move in the decking board through which they had been driven.

In some instances, so few functional nails remained in a given deck board that the board was practically free-standing and unattached. Several single deck boards were held in place by no more than two or three functional through-nails and with no toenails. In some cases the decking was split at the toenail positions, and when the decking was lifted out of the bridge, the toenails remained in the stringers. Very little splitting was observed in relation to through-nailing in the decking.

Moisture Content Upon Removal

The removal of the old decking and the inspection of individual boards made it possible to take moisture content measurements of the decking in a manner that had not previously been possible. Using an electric, resistance-type moisture meter with 1-1/2-inch needle electrodes, readings were taken at different depths through the deck boards at positions in grain alinement with through-nail holes and at random points away from any such holes. Reading depths were 1/4 inch, 1/2 inch, and 1 inch, the latter being approximately half-way through the board thickness. The results obtained are shown in table 1.

Although the moisture content measurements were made at the end of an extended dry summer period, over one-half of the measurements showed a moisture content of the wood at or above fiber saturation (30 pct. moisture content). The most significant aspect of these measurements and observations is that moisture contents sufficiently high to constitute distinct decay hazards were common in the interior, untreated portions of the decking. There is little question that much more wetting would have been present had the decking been removed and the measurements made in early summer near the end of the rainy season. Boards tended to have higher moisture contents at 1-inch (center) depths than at 1/2- or 1/4-inch depths, and probably reflect the presence in the shallower depth of the oily preservative. Further, little more wetting was observed in grain positions alined with and adjacent to the nail holes than occurred at random points not in line with or close to nail holes.

Decay

One of the most significant parts of this project was an individual examination of the deck boards as they were removed from the bridge and

Table 1.--Moisture content of decking[1] removed from the Panther Creek Bridge after 12 years of service

Sample board No.	Moisture content of three reading depths--		
	1/4 inch	1/2 inch	1 inch
	Pct.	Pct.	Pct.
READING POINTS IN GRAIN ALINEMENT WITH NAIL HOLES			
1	27	22	28
2	26	38	42
3	22	23	36
4	28	38	38
5	21	25	28
6	25	32	40
7	22	29	30
8	25	30	27
9	25	22	24
10	27	27	31
11	23	25	28
12	21	26	30
13	25	28	33
14	23	24	26
Subgroup average	24.3	27.8	31.5
READING POINTS NOT ALINED WITH NAIL HOLES			
15	22	27	28
16	24	28	29
17	22	27	29
18	29	25	24
19	26	34	30
20	19	26	27
21	26	36	34
22	19	25	27
23	24	30	32
24	23	26	29
25	34	22	34
26	23	24	25
27	25	29	33
28	25	27	30
29	33	32	32

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Table 1.--Moisture content of decking[1] removed from the Panther Creek Bridge after 12 years of service--continued

Sample board No.	Moisture content of three reading depths--		
	1/4 inch	1/2 inch	1 inch
	Pct.	Pct.	Pct.
READING POINTS NOT ALINED WITH NAIL HOLES--continued			
30	28	28	29
31	30	33	33
32	28	31	31
33	29	27	28
34	34	31	31
Subgroup average	26.1	28.4	29.7
Overall average	25.4	28.1	30.5

[1]This decking was removed from the bridge 11 days before these moisture measurements. The readings were obtained with an electric, resistance-type moisture meter using 1-1/2-in. needle electrodes directed into the flat face of the boards.

during the selection of decking for replacement on one-third of the bridge length. Every piece of old decking tentatively selected for reuse was probed at all nail holes in an effort to avoid the reuse of any pieces having decay. Approximately 20 percent of the deck boards so examined were rejected due to definite decay. Additional material was rejected because of the questionable character of the wet wood. Considerable difficulty was experienced in attempting to determine the presence of incipient decay at or adjacent to nail holes by the simple process of probing the wood with a fine-bladed screwdriver. Many of the decking boards had been cut from fast-grown, young trees so material having moderately wide annual rings was common. Probing such material in a wet and, therefore, softened condition made it difficult to distinguish between incipient decay-softened wood and wet wood. In many cases, there was no question about the presence of decay due to the excessively soft conditions. Decay was evident also when such boards were sawn into short lengths and inspected visually. Based on the probing survey, it was estimated that one-quarter or more of the pressure-treated deck planks had incipient or advanced decay at some point in the interior, untreated wood.

Approximately 40 short samples of Douglas-fir decking, sawn from the material removed from the Panther Creek Bridge, were returned to the Forest Products Laboratory for further appraisal. At the Laboratory, clean-cut cross-sectional blocks, approximately 1/2 inch long in the grain direction, were cut from these samples to appraise both preservative penetration and the presence of decay and iron stain. Fifteen of these samples are pictured in figures 10, 11, and 12. The most conspicuous aspect of this series of pictures is the relatively poor preservative penetration obtained from the creosote pressure treatment. In these pictures, darkening of the interior wood is frequently the result of iron stain and not an indication of preservative penetration.

Indistinct decay areas are indicated in the figures by dotted boundaries. In several instances, the decay did not become readily apparent visually until the short block sections had been dried at which time both the incipient and advanced decay underwent distinctly abnormal shrinkage.

Decay, when present, was consistently located in grain alinement with either the through-nailing holes, the toenailing holes, or the holes through which the steel tread hold-down bolts were positioned. Positioning of the decay in line with the fastener holes is very probably attributable to three factors: First, wetting of the untreated interior wood most frequently occurred through the fastener holes and resulted in a moisture buildup sufficient to support active decay. Second, the wet wood adjacent to the iron fasteners was discolored frequently by the precipitation of iron tannate, resulting in the common iron stain of the wood. It has been shown previously that the formation of such iron stain in Douglas-fir heartwood lowers its natural decay resistance. Third, the same avenue for water entry into the decking (nail holes) had likely been

the avenue for fungus spore entry into the wood along with the water. In almost all cases observed, the decay present had occurred in the heartwood and not the sapwood, the latter having been adequately preservative treated. This estimate of heartwood was based on the color of the wood adjacent to the decayed area.

Some of the deck boards not pictured in this report showed greater preservative penetration, and in some cases almost complete penetration where no decay was detected. The problem of decay in preservative-treated decking stems from the fact that a fairly high percentage of the boards, when treated without incising, fail to be adequately penetrated by oilborne preservatives.

The effect of the observed decay on the strength of the deck laminates was not measured. However, the localization of the decayed areas at through-nail points results in the decay being positioned predominantly away from the center or neutral axis of the deck laminates and usually near but not at the upper or lower edge of the members. Therefore, the larger areas of such decay must be assumed to have a weakening effect since they involve loss of material adjacent to either the compression or tension faces of the inplace laminates. It is important to recognize that, without corrective measures, all such decay infections of the existing bridges in high rainfall areas will probably develop at a continuously increasing rate, resulting in an associated loss of strength.

The decayed areas at the decking toenail holes are initially less critical than the decay at through-nail positions in weakening the deck laminates since the former are uniformly positioned over the supporting stringers. Such areas may become critical in advanced decay stages however, since they may develop crushing failures just above the stringer-deck interfaces and do unquestionably contribute to increased loosening of the deck.

Isolating and determining the magnitude of strength loss due to decay and its effect on deck function will be difficult because of the interdependency of deck strength on factors such as failed fasteners, loosely spaced laminates, nonsupport at stringer crossings, and hidden defects such as knots in the laminates. Certainly the decay at through-nail and toe-nail points is critical in terms of deck strength. Obviously the effectiveness of any fastener in decayed wood is largely lost.

Movement and Mechanical Wear

One significant problem observed that has likely resulted from fastener failures, excessive deck movement, and considerable abrasive wear of decking and stringers was the lack of stringer support of deck boards. This condition was observed primarily along the center stringer of both the main and the east approach spans. Characteristically, all deck boards for a distance of 1 to 6 feet at intermittent spacings along

the length of the stringers stood clear of the stringer top by from 1/8 to 3/8 inch. Toenails in these areas were either loose in the stringer nail holes, or broken, or the decking was split out at the toenail positions leaving the nails bent over in the stringers (fig. 13). Crossings by logging trucks and other vehicles caused these unsupported deck boards to be banged repeatedly onto the stringer tops, resulting in mechanical wear.

This pounding and the associated decking movements were made more serious by the presence of mud and sand accumulations between the deck boards and along the top of the stringers. This material causes the decking movement and pounding contacts to be abrasive, with a resulting loss of the thin layer of preservative-treated wood from the lower edges of some deck boards. The bottoms of the deck boards in such areas were slightly rounded and worn to depths of 1/4 inch or slightly more, corresponding to the shape of the stringer cross section (fig. 14).

Stringer Observations

Wear

Stringer tops showed corresponding wear, but were characteristically scalloped in a pattern corresponding to the rounded lower edges of the adjacent deck planks (figs. 9 and 13). No accurate measurement of material loss was obtained on the stringer tops, but in some areas most of the preservative-penetrated wood had been removed. This probably represented a loss of surface material from 1/16 to 3/16 inch in depth.

Surface Splitting and Checking

Longitudinal splitting and checking in the upper laminate was frequently observed in the stringer tops. Commonly, splitting occurred at toenail holes and less frequently checking was noted, independent of any nailing and essentially being large seasoning checks (figs. 15 and 16). In either case, such splits and checks far exceeded the depth of preservative penetration in the stringer tops as did the toenail penetrations. A very considerable variation in this regard appeared to be associated with the individual upper laminates of the stringers.

Possibly correlated with the presence or absence of checks was the variable degree of preservative treatment observed. In some cases, the upper laminate appeared to have taken treatment quite well. Some of these well-treated boards resulted simply from the presence of sapwood.

In other cases, there was no question that some heartwood laminates had been adequately treated. There seemed to be a tendency for the well-treated boards to show little or no checking and for some of the poorly treated upper laminates to show considerable checking. This reaction may be associated with the effect of the creosote treatment in appreciably retarding the rate of wetting and drying of the upper laminates where good creosote penetrations and retentions were obtained. A larger sample would be required to confirm this tendency.

Moisture Content

With the decking removed, moisture content of the stringer top laminates was determined at 77 points using the electric moisture meter and with readings taken at depths of 1/4, 1/2, 1, 1-1/2, and 2 inches at each point as the 3-inch electrodes were driven into the stringer tops. Points selected for readings were generally in grain alinement with toenail holes but 1 to 3 inches away from the holes. The readings obtained are shown in table 2. At 30 of the 77 positions, or 39 percent of the positions, readings of 30 percent or higher were registered at one or more depths in the upper laminates. Thirty percent moisture content represents the approximate minimum level of moisture that will support decay and is generally considered the lower limit of a decay-hazardous moisture level range. These moisture determinations were made before stringers were wetted by the rains that followed deck removal, and probably represent the driest condition in the stringers for almost a year.

Iron stain was observed frequently in cores removed from the stringers and in areas where the upper stringer surface was worn free of preservative. Such stain appeared to have been associated with toenails. Some iron-stained areas of wood were dry, but the presence of the stain showed that the wood had been wet previously.

Decay

Every nail hole in the stringer tops from which deck nails had been withdrawn was probed for decay. The same problem of distinguishing between incipient decay and wet wood was experienced during such probing as described earlier for deck probing. Probing could not clearly distinguish the sound, but wet and thereby softened, earlywood of the Douglas-fir laminates from possible incipient decay. No stringer decay was definitely located by probing but questionable areas were noted and marked for core examination. Subsequent coring of the marked areas using a 3/8-inch plug cutter with an electric drill provided cores for a visual check on the questionable material. All coring holes were plugged with creosote pressure-treated, hardwood dowels and these were trimmed flush with the stringer surface.

Table 2.--Moisture content in the upper laminates of Panther Creek Bridge stringers[1] as determined in September 1969 after deck removal

Distance from end of stringer		Moisture content at five reading depths--				
		1/4 inch	1/2 inch	1 inch	1-1/2 inches	2 inches
Ft.	In.	Pct.	Pct.	Pct.	Pct.	Pct.
CENTER STRINGER, NORTHEAST APPROACH SPAN						
From East End						
3		22	23	24	23	23
3	6	23	24	26	27	26
4		29	29	28	28	29
5		28	27	26	22	22
5	4	30	34	30	29	25
5	6	30	27	27	23	22
5	8	19	19	20	20	20
7	6	19	20	22	20	21
11	6	19	19	20	24	22
12	6	25	27	30	30	28
14	6	17	18	20	20	20
14	8	17	15	16	18	17
21		17	17	18	21	21
23	6	21	20	25	18	17
CENTER STRINGER, MAIN SPAN						
2		21	22	23	21	20
7		18	18	20	20	21
11		14	15	14	13	13
18		18	19	21	24	28
22		30	34	34	31	29
22	3	34	34	32	25	25
27		21	22	22	24	24
28	6	14	15	16	17	18
32	6	16	17	18	19	19
33		12	13	14	14	14
40		13	15	17	18	16
41		12	12	12	13	14
45		12	12	12	13	16
47	6	13	12	13	14	17
49		12	13	13	14	18

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Table 2.--Moisture content in the upper laminates of Panther Creek Bridge stringers[1] as determined in September 1969 after deck removal--continued

Distance from end of stringer		Moisture content at five reading depths--				
		1/4 inch	1/2 inch	1 inch	1-1/2 inches	2 inches
Ft.	In.	Pct.	Pct.	Pct.	Pct.	Pct.
		CENTER STRINGER, SOUTHWEST SPAN				
From East End						
1		17	19	21	21	20
1	6	23	22	18	17	16
10		26	23	32	40	34
13	6	19	18	17	16	15
20		24	24	26	26	25
25		33	34	35	30	29
		SOUTH STRINGER, NORTHEAST APPROACH SPAN				
From West End						
4		16	15	17	16	17
5	6	17	16	18	18	18
11		23	22	18	20	29
13		20	25	24	20	20
17		30	35	40	45	35
21	4	32	35	35	40	22
23	6	36	33	26	24	23
		SOUTH STRINGER, MAIN SPAN				
From East End						
2	6	17	18	19	21	18
5	6	33	33	32	27	24
9	3	37	39	41	35	33
12		33	33	39	37	27
12	6	34	35	39	40	34
15		20	26	36	40	23
17	6	21	19	18	20	20
20		24	20	17	15	16
30		27	32	43	39	20
40		38	36	32	27	22

Table 2.--Moisture content in the upper laminates of Panther Creek Bridge stringers[1] as determined in September 1969 after deck removal--continued

Distance from end of stringer		Moisture content at five reading depths--				
		1/4 inch	1/2 inch	1 inch	1-1/2 inches	2 inches
Ft.	In.	Pct.	Pct.	Pct.	Pct.	Pct.
		SOUTH STRINGER, SOUTHWEST APPROACH SPAN				
From East End						
0	4 (inside)	19	21	28	34	35
0	4 (outside)	21	18	19	17	16
4	6	22	17	17	16	16
10		24	26	34	37	32
10	6	27	32	45	60	65+
13		26	27	28	36	38
13	6	18	20	22	22	23
27		20	21	23	22	23
		NORTH STRINGER, NORTHEAST APPROACH SPAN				
16		27	27	33	33	28
17		13	20	24	23	23
18		15	19	20	21	22
19		16	19	20	20	20
23		16	25	24	23	22
		NORTH STRINGER, MAIN SPAN				
3	6	18	19	20	19	20
8	6	30	35	35	25	25
12	6	30	28	23	22	22
20		32	36	28	20	21
21		37	36	32	22	21
24		37	36	29	19	20
29		20	18	20	21	22

Table 2.--Moisture content in the upper laminates of Panther Creek Bridge stringers[1] as determined in September 1969 after deck removal--continued

Distance from end of stringer		Moisture content at five reading depths--				
		1/4 inch	1/2 inch	1 inch	1-1/2 inches	2 inches
Ft.	In.	Pct.	Pct.	Pct.	Pct.	Pct.
		NORTH STRINGER, SOUTHWEST APPROACH SPAN				
From East End						
0	6	27	19	34	39	38
8	6	19	17	16	18	17
10		28	39	45	47	44
11	6	27	26	29	45	22
18	6	20	21	22	23	22

[1] Moisture determinations were made with an electric moisture meter (resistance type) with 3-in. electrodes positioned vertically and driven down into the upper and second laminates of the stringers after deck removal. The electrodes were commonly placed in grain alinement with toenail holes in the wood. Generally, moisture contents are lower in this set of readings than would be the case at an earlier or later date, since these were taken at the end of the summer after an extended, rain-free period.

Definite advanced decay was encountered in the downstream (south) main span stringer at a point 12 feet from its northeast end. The decay was below approximately 1 inch of wet, top-lamination wood and extended down into the second lamination. The area limits of the advanced stage of decay were determined by additional coring. This area of typical decay extended a total length of 18 inches in the grain direction. At its maximum the decayed area was approximately 3 inches wide and 2 to 3 inches deep. High moisture contents in the wood of the top lamination extended longitudinally from the decay for several feet in both directions, indicating that fungus spread would not be limited by lack of moisture.

The decay-causing fungus was living and vigorous as indicated by its immediate vegetative growth from the cores after storage in snap-capped, sterile tubes. What appeared to be the same decay fungus developed in a number of cores taken adjacent to this stringer area, but which did not appear to represent typical or advanced decay. Undoubtedly, incipient decay or infection extended 1 to 2 feet beyond each end of the easily identified area of advanced decay.

Water entry into the top lamination of this stringer had occurred through both nail holes and a long check. Many additional areas in the upper laminations of other stringers were equally wet, but no other typical decay was found. Further, no additional areas of incipient decay were definitely located, although several questionable areas were encountered by core appraisal. Some of the questionable areas showed high moisture contents in untreated wood that was distinctly iron-stained.

The advanced or typical decay definitely noted in the south main span stringer has not likely weakened the stringer significantly to date, primarily because of the small cross-sectional area of decay and that the area affected is loaded in compression only. However, the decay infection in this area is estimated to be only 3 to 4 years old and can be expected to continue to spread at an estimated annual rate of 10 inches longitudinally and an inch laterally unless preventive measures are taken to inhibit further development. This could entail either early drying to a safe level of wood moisture or inplace treating with local application of a toxic wood preserving chemical.

Redecking Activity

Approximately one-third of the bridge length (32 ft.) was redecked with glued-laminated deck panels[3] and two-thirds with nailed-laminated decking. One-half of the nailed-laminated decking was new, kiln-dried, and creosote pressure-treated material and the other half was salvaged deck boards from the old bridge deck which were originally creosote pressure treated. The old decking represented material at a moisture content approximately comparable to new, green-treated decking.

The Panther Creek project provided an opportunity to evaluate, under like-service conditions, the relative effectiveness of the three types of decking. It is believed that the kiln-dried decking will be more stable than the highly moist decking salvaged from the old deck. Also, from other field observations and a related laboratory project, it seems clear that the characteristics of the glued-laminated decking are superior to a nailed-laminated system. The glued slabs have much to offer in protecting bridges from decay, since they will normally support an asphalt mat more securely and firmly than the nailed decks, particularly on bridges with widely spaced stringers.

Before replacement of the decking, it was necessary to use a commercial floor sander to sand the upper surface of two of the center stringers to eliminate the scalloped or rippled irregularities from deck wear and to obtain a smooth support surface. Only the high points were removed. It was then necessary to nail a single thickness of 1/4-inch plywood on the surface of the middle stringer to bring its level up to the approximate level of the two outer stringers. The stringer tops and the plywood were brush treated with pentachlorophenol wood preservative before replacement of the decking.

Comparative Cost of Material and Installation

The material cost for the glued deck slabs is greater than for the nailed decking. However, the field installation costs of the glued system will be less. This project offered an opportunity to compare the material and installation costs of the two decking systems:

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[3] An appraisal of experimental panels similar to those used is available in a thesis, "Glued-Laminated Wood Panels For Highway Bridge Decks," a Master of Science thesis by Leon B. Boland, 1969, Dep. of Civil Eng., Univ. of Wis. Additional consideration of deck panels as tried on bridges is covered in the article "Timber Bridges Go Mod," by Roger Tuomi and Billy Bohannan, Wood Preserving, Dec. 1971.

Table 3.--Moisture content of new kiln-dried, pressure-treated decking for Panther Creek Bridge a few weeks after delivery[1]

Sample board No.	Moisture content at four reading depths--			
	1/4 inch	1/2 inch	1 inch	1-1/2 inches
	Pct.	Pct.	Pct.	Pct.
1	14.7	10.4	10.0	9.3
2	11.2	12.0	13.0	9.7
3	11.0	10.0	10.5	12.5
4	11.3	9.6	10.9	12.0
5	11.1	9.3	9.0	13.0
6	14.0	10.2	10.7	11.5
7	13.5	10.1	11.2	10.6
8	13.4	11.5	11.3	11.6
9	12.5	14.2	15.2	10.7
10	9.7	9.3	10.3	10.3
11	11.5	9.6	10.6	9.2
12	10.6	10.4	12.0	11.0
13	12.0	12.0	12.0	10.0
14	13.0	9.4	9.2	11.5
15	10.0	9.4	9.1	9.1
16	12.8	9.6	9.6	10.4
17	11.6	11.9	14.2	10.9
18	12.4	12.0	12.0	10.3
19	12.9	12.9	14.0	12.0
20	12.8	9.9	10.8	9.5
Average	12.1	10.6	11.3	10.8

[1] Kiln-dried, pressure-treated, 2- by 8-in. Douglas-fir boards. Readings were taken Nov. 14, 1968, several weeks after the decking was delivered near the bridge site.

	Glued-laminated	Nailed-laminated
Material		
Cost per linear foot	$98.80 + $0.50 = $ 99.30	$37.20 + $4 = $41.20
Installation (labor)		
Cost per foot	$ 4.75	$28.00
Total	$104.05	$69.20

This analysis indicates that the glued-laminated slab construction is much more expensive than that of nail-laminated decking. However, it is clear from other studies that the potential of the glued system for service longevity is much greater. Also, the bid prices received for the glued components of this project were extremely high at $750 per thousand board feet. This price should be lower in more competitive bidding situations.

Nailed-Laminated Decking

The nailed-laminated, 2- by 8-inch decking was installed with through-nailing and toenailing systems normally used by the Forest Service. Due to the extent of observed nail failure of the thirtypenny nails in the dismantled deck, fortypenny nails were used in the replacement of both the new and salvaged decking.

The kiln-dried and creosote pressure-treated decking, although left uncovered and poorly stacked near the bridge site for almost a year, had apparently increased very little in moisture content, even in the relatively wet environment of the area (annual precipitation averages 99 in.). Moisture content determinations were made in November 1968 and again on September 29, 1969 (tables 3 and 4). This material is expected to show little or no shrinkage as the bridge continues in service. Unfortunately, the material was not incised as originally specified and the preservative treatment is less effective in penetration and retention than it would have been with incising.

From the salvaged original decking removed from the Panther Creek Bridge, a sufficient amount to redeck one-third of the bridge was inspected and carefully selected to eliminate boards with detectable decay. These deck boards were quite wet and commonly had a moisture content near or above fiber saturation (table 1). These members will undoubtedly show considerable shrinkage if the deck can be dried in place.

Table 4.--Moisture content of kiln-dried, pressure-treated decking on September 29, 1969, approximately 1 year after delivery to the bridge site in October 1968[1]

Sample board No.	Moisture content of three reading depths-- 1/4 inch	1/2 inch	1 inch
	Pct.	Pct.	Pct.
READINGS THROUGH EDGE OF MEMBERS			
1	12	12	12
2	15	16	17
3	12	11	11
4	11	11	12
5	11	11	11
6	12	11	12
7	12	11	11
8	12	12	12
9	11	11	12
10	13	12	12
11	12	12	13
12	13	12	12
13	13	11	12
14	11	11	12
Subgroup average	12.1	11.7	12.2
READINGS THROUGH CENTER OF FLAT FACE			
15	13	13	13
16	11	11	11
17	12	13	14
18	9	9	9
19	9	9	9
20	9	9	9
21	9	9	9
22	9	9	9
23	9	9	9
24	9	9	9

Table 4.--Moisture content of kiln-dried, pressure-treated decking on September 29, 1969, approximately 1 year after delivery to the bridge site in October 1968[1]--continued

Sample board No.	Moisture content of three reading depths--		
	1/4 inch	1/2 inch	1 inch
	Pct.	Pct.	Pct.
READINGS THROUGH CENTER OF FLAT FACE--continued			
25	16	15	14
26	12	12	12
27	12	14	12
28	13	13	14
Subgroup average	10.9	11.0	10.9
Overall average	11.5	11.3	11.5

[1]The decking was poorly stacked and not covered during the exposure period and thus subject to rain and snow wetting. Use of the decking as kiln-dried and conditioned material was consequently questioned. Boards sampled were randomly selected and not necessarily the same as those measured and shown in table 3.

Table 5.--Moisture content of glued-laminated deck slabs after installation on the Panther Creek Bridge,[1] October 1, 1969

Deck slab and laminate No.	Moisture content at three reading depths--		
	1/4 inch	1/2 inch	1 inch
	Pct.	Pct.	Pct.
1-A	12.0	10.2	11.1
1-B	11.9	10.2	10.8
1-C	11.8	11.2	11.7
2-A	11.7	11.8	12.0
2-B	12.2	11.6	11.8
2-C	12.1	11.9	12.0
3-A	11.5	11.4	11.6
3-B	12.1	11.0	11.7
3-C	11.0	10.5	10.7
4-A	11.0	11.4	11.6
4-B	11.1	11.5	11.7
4-C	12.4	11.3	12.0
5-A	12.0	11.7	12.0
5-B	11.9	12.1	12.0
5-C	11.0	11.1	11.9
6-A	13.1	13.8	14.7
6-B	11.4	11.3	12.1
6-C	12.1	12.0	12.2

[1] These deck slabs were exposed in outdoor, uncovered stacks for a period of nearly 1 yr. prior to Sept. 1969 at the Hemlock Ranger Station, Stevens, Wash.

Glued-Laminated Panels

The glued deck panels for this project were vertically laminated of nominal 2- by 8-inch, Construction grade, coast region Douglas-fir. They were surfaced after gluing to a net thickness of 7 inches. The plan view dimensions are 4 feet 0 inches by 15 feet 6 inches. Preservative treatment was specified as a 50-50 mixture of creosote and heavy petroleum oil.

The maximum moisture content specified for the laminations before manufacture was 15 percent. After a year of outdoor exposure at the storage site near the Hemlock Ranger Station, the average moisture content as determined by 54 readings with an electrical (resistance type) moisture meter at depths of 1/4 to 1 inch was about 12 percent (table 5).

Panel installation began at the southwest end of the bridge and continued over the entire length of that approach span and approximately 5 feet onto the main central span. Figure 17 shows the second 4-foot panel being hauled into position by a small forklift truck. Figure 18 shows the 10-inch-long, 1-inch-diameter steel dowels that were used to transfer vertical shear between panels. Dowels were spaced 7 inches apart.

The dowels were slightly beveled at each end for ease of penetration into the predrilled, pretreated dowel holes in the edges of the panels. They were dipped in light oil immediately before insertion. The panels were drawn together with the backhoe with no difficulty.

After the panels were drawn into place, half of them were nailed to the stringers with 12-inch-long, 3/8-inch-diameter ring-shank nails. Due to a shortage of these nails, a substitute brand was used on the remaining half of the panels. The substitute nails were the same diameter but were 2 inches shorter than the ring-shank nails and, instead of concentric rings, their penetrating ends were twisted, rectangular sections 3-1/2 inches long. The top 3 inches of each nail hole was 1-1/4 inches in diameter to allow for a steel washer under the head of each nail and for countersinking the washers and nailheads. The nails were driven into field-drilled, field-preservative-treated, 1/4-inch-diameter lead holes in the stringers. Figure 19 shows the nailing on panel No. 1. After the nails had been driven home in the counter bores, a bituminous sealing compound was poured into the finished holes to eliminate water penetration into the nail-hole area.

Use of two different nail types provides an opportunity for side-by-side comparison of nail effectiveness. During the first post-construction inspection in April 1970, it was not possible to detect any malfunction in either nail type.

Since the redecked Panther Creek Bridge was to receive an asphalt mat over its entire length, it seemed probable that a sealant between deck

Table 6.--Moisture content at 38 permanent probes in the top laminates of the Panther Creek Bridge stringers on October 3, 1969[1]

Moisture probe No.	Moisture content	Moisture probe No.	Moisture content	Moisture probe No.	Moisture content
	Pct.		Pct.		Pct.
11	32	377	45	486	13
12	25	399	45	490	22
13	31	406	47	502	30
14	25	422	45	504	30
15	32	450	46	506	47
16	35	456	52	507	21
112	27	457	26	510	47
161	56	462	21	515	47
173	46	463	49	521	42
191	50	467	49	522	25
325	16	471	19	523	51
326	20	478	50	526	46
343	47	484	25		

[1]These readings were obtained from both the old and the new probes established in Sept. 1969, and the readings have been corrected for the prevailing wood temperature.

panels would not be necessary. However, during reconstruction it was decided to use a sealant between deck panels of the last half of these units when they were installed to protect the stringers against further wetting in case of mat cracking or other mat defects. This was done by applying a generous coating of coal-tar mastic on the interfaces before they were forced together. A generous "squeeze-out" of mastic which appeared after drawing the panels together indicated that the sealing effort was effective. Unless the mastic drips from the vertical joint, which is highly unlikely, or the panels split in use, this type of deck should be watertight. The first inspection (April 1970) indicated no decline in watertightness.

Additional Moisture Probes

After the redecking was completed, additional permanent moisture probes were established in the upper laminates of the glued-laminated stringers. These probes were needed to provide moisture measurements that would reflect the rate of drying of wet stringer wood under the three deck types and the new asphalt mat. Data from the probes also will be useful in appraising the effectiveness of the mat as a moisture seal to prevent water passage through the three different deck types. Table 6 shows the moisture contents of the stringer wood shortly after the new probes registered equilibrium readings in October 1969. Twenty of the 38 probes (53 pct.) showed readings of 30 percent or above and 18 probes (47 pct.) showed readings of 40 percent or higher.

Asphalt Deck Mat

Several weeks after the bridge deck had been rebuilt, the Forest Service road crew placed an asphalt mat[4] on the full length of the deck. The desired asphalt had not been obtainable, and as a consequence, the crew took the material that was currently available from the mixing plant for use on the bridge. It was not possible to learn exactly what mix, aggregate grades, and proportions were used for the new mat but the following information was obtained:

(1) The deck surface was cleaned and a tack-coat applied consisting of an SSK emulsified asphalt.

[4] Information on mat application and available information on composition was supplied by Paul Grooms of the Gifford Pinchot engineering staff.

(2) The mat proper was placed after an appropriate "cure" of the tack-coat and consisted of an unspecified hot mix which was compacted with a roller.

(3) Two weeks later and after it was evident that the new mat was allowing water passage through the deck, a seal coat was applied over the entire mat surface. This consisted of a sprayed-on SSK emulsion followed by a 1/4-minus chip seal.

A short time after the seal coat was applied, apparent moisture penetration through the decking had stopped. Unfortunately, some time later a crossing, cleated-track tractor broke the seal coat at repeated points so that water is again moving through the mat to cause additional deck and stringer wetting. The mat was resealed during the summer of 1970.

Discussion and Conclusions

Since this bridge is very similar in construction to many others, it seems highly probable that the stages of decay found in the Panther Creek Bridge reasonably represent what may be occurring in other bridges of similar age and wetness. Moisture conditions at many points throughout the decking and stringer tops were commonly high enough to support decay even though this inspection was made when the moisture content of the bridge members could be expected to be at a minimal level for the year. Probably significant decay infections exist in comparable aged bridges of similar design in areas having a considerably lower annual rainfall than the Panther Creek area (99 in. per year).

Advanced decay in the 12-year-old Panther Creek Bridge was present at many points in the decking, and was also detected in one main span stringer. Incipient decay was present in additional areas of deck samples brought to the Laboratory; based on this sample, early stages of decay also must be common at many points in the old decking. Such incipient decay was not confirmed as being present in the stringers, but some infected areas are suspected. Thus, it would appear that decay fungi are becoming well established at numerous points in the untreated portions of the moderately decay-resistant, wet, Douglas-fir heartwood.

One of the most important conclusions that can now be drawn from the Panther Creek deck removal and inspection project is the fact that a number of Forest Service bridges of the glued-laminated-stringer, nailed-laminated-deck type, and located in the high rainfall area west of the Cascade crest, are not likely to give the service life expected from them without some early modification to curtail developing decay. This deficiency is a result of at least three definite factors:

(1) Inadequate deck fasteners for the commonly occurring loads as regards the decking spans and the deck fasteners used.

(2) Inadequate penetration of preservative treatments in Douglas-fir heartwood in both decking and stringer tops due to the lack of incising before treatment.

(3) Deck wood shrinkage coupled with possibly loosely laid decking, accounting for some additional deck loosening, particularly after several years of service and exposure with a resulting increase in deck member movements that account for nail flexing and failure.

A fourth factor, unusually severe overloading, also may have contributed to the early failure of fasteners and increased deck loosening.

Considering the decay now present in the decking and stringers, it will soon be necessary to apply corrective measures to curtail further decay if the decking and stringers in the 10-year-old and older bridges are to remain useful. Early action is necessary since no anticipated corrective measure will immediately stop decay because the deeply wetted wood will probably dry slowly.

Recommendations

One possibly effective modification would be a high-quality asphalt mat adequately supported by a stable deck. The mat should be applied with an appropriate tack-coat and also should be seal-coated and maintained to prevent further passage of water into the decking and stringer members. This assumes that decay has not weakened the decking beyond use and that the decking is attached to the stringers securely enough so that excessive deck movements will not prevent satisfactory performance of the asphalt mat. Bridges with nailed-laminated decks that are inadequate to support protective mats should be redecked with a glued-laminated slab decking, which appears to offer adequate stiffness and stability to support the mat.

The relatively high cost of glued-laminated deck slabs naturally affects these recommendations. But a large-scale purchase of such slabs might appreciably reduce unit costs of such material. Storage or stocking such material should not create a particular problem since the preservative treatment should be completely protective if outdoor storage is necessary. This is largely assured by the fact that the slab laminates are predried before gluing and the slabs are prebored before pressure treatment.

It is further recommended that a systematic, inplace, preservative treatment be applied to the stringer tops as a part of any redecking procedure. Such treatment would focus on nail and bolt hole areas and wood adjacent to any checks or splits exposed during removal of the old deck. Treating holes 1/4 or 3/8 inch in diameter, and bored systematically

at points appropriate for introducing the preservative, will aid in the effective application and distribution of the preservative in the upper two laminates. A water-soluble preservative should be used so as to take advantage of the high moisture content of the upper laminates to diffuse the preservative.

In the past little attention has been given to selecting specific materials for bridge mat use; whatever material was available at the mixing plant nearest the bridge site was generally used. Before the late 1960's, the use of seal-coat applications to obtain maximum water-shedding characteristics of asphalt mats on Forest Service bridges has not come to the attention of the writer. Further, mat design and choice of material has seldom considered the logical aim of shedding water from the bridge structure. Rather, the mat has been designed primarily to prevent mechanical wheel-tread damage to the deck surface. Evidence of deck mat repair on state and county secondary road bridges near the Gulf Coast has been observed repeatedly. Would it not be practical to maintain mats systematically on Forest Service bridges?

It is strongly recommended that specific data be obtained and recorded regarding the asphalt mixture (aggregate size and ratios), oils used and amounts, tack-coat materials, seal-coat materials, and any other specifics related to asphalt mats established in the near future. The data are essential for future appraisal and comparison of the mats. Practically no data for the older existing mats are now available. There will be two and possibly three more mats established under this program on existing or new bridges. Some engineering supervision should be provided to ensure that data are recorded for these mats.

If new nailed-laminated decking is scheduled for use in repair, replacement, or new bridge construction, and there is no assurance of a well-maintained asphalt mat to protect the bridge members from hazardous wetting, we strongly recommend that the decking be incised before pressure treatment. With incising a more uniform and deeper preservative treatment is obtainable. If feasible, kiln-dried decking material should be used to reduce the loosening that results as green deck members season and shrink.

Followup Study

The Panther Creek Bridge will continue to be of interest to engineers and further observations should be made as a check on the following:

(1) Comparative durability and resistance to cracking of the asphalt mat resulting from the support provided by the three deck types.

(2) The relative effectiveness and durability of the seal-coated asphalt mat as a barrier to further water penetration through the decking.

(3) The rate of drying in the 12-year-old, reused decking under the asphalt mat. Moisture probes could be set in the decking for this purpose or moisture readings taken with 3-inch-needle electrodes. The latter method would be subject to more error and less accurate information would be obtained. This decking has roughly the moisture level commonly present in new, pressure-treated decking where the material is treated in an essentially green condition.

(4) The upper laminates of the glued-laminated stringers, which are hazardously wet at numerous points, will probably dry slowly. With the additional probes installed in September 1969, there are now 38 permanent moisture-sensing elements established in the bridge stringers. The results from these probes should provide data to appraise what type of action can be taken to correct the existing conditions on other Forest Service bridges in the Far West.

(5) The asphalt mat on the Panther Creek Bridge should be compared with the new and somewhat similar mat recently established on the Soleduck Bridge, Olympic National Forest. The two mats apparently represent different types of asphalt mixes, tack-coating procedures, and seal coating.

(6) The mechanical characteristics of the three decking materials--fastener effectiveness, shrinkage or swelling, and the practical serviceability of the contrasting materials--should be appraised.

Figure 1.--Panther Creek Bridge decking after the removal of the tread plates. Tread-plate areas on the decking are evident from the imprinted pattern in the deck surface and particularly at the ends of loosened tread plates where the abrasion and gouging of the deck boards exposed the untreated wood. (M 138 118)

Figure 2.--Accumulation of soil on the deck between tread plate and wheel guard. The soil holds water on the deck surface and, at the depth shown, blocks lateral water drainage from the deck surface. Although such accumulations may be present only during the summer and fall, the resulting increase in bridge member wetting comes at a period when temperatures are favorable for decay. (M 138 106)

Figure 3.--The removal of decking boards was facilitated by steel spuds. Virtually no damage to either the decking or the nail fasteners resulted from systematically prying loose the individual deck boards. (M 138 111)

Figure 4.--Open spaces between deck boards of the old nailed-laminated deck on the Panther Creek Bridge after removal of the steel tread plates. This juncture of main and approach span stringers represents the worst decking condition observed on this bridge. (M 138 113)

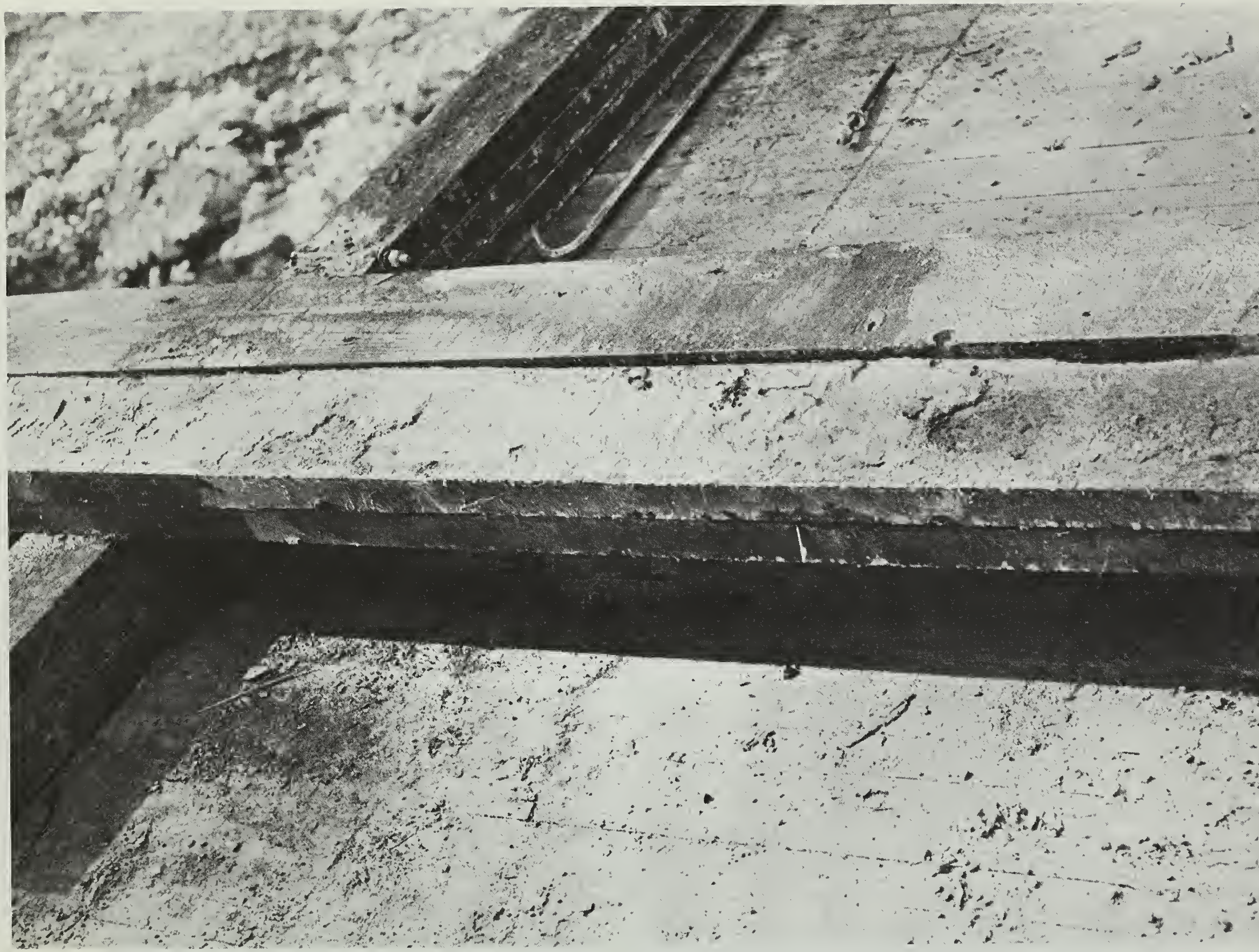

Figure 5.--Many of the decking boards had firmly adhering layers of creosote and sandy loam soil. These accumulations of material between the inplace boards represented open spacing between the boards amounting to as much as 1/2 inch. (M 138 114)

Figure 6.--Cleaning the salvaged decking before inspection and selection of boards for redecking one-third of the bridge length was often tedious and time consuming. The workers used both an adze and a steel spud to scrape the soil and creosote from the board surfaces. (M 138 110)

Figure 7.--Severely deformed or broken nails were commonly encountered throughout the deck removal operation. Many nails showed a reduction in cross-sectional diameter, usually in the form of tapering (top row in figure). Also, a large number of through-nails in the deck planks were broken from flexural fatigue at intervals varying from 1 to 2-1/2 inches (bottom row). (M 137 175)

Figure 8.--Additional Panther Creek Bridge fasteners collected during the deck removal operation. Many of the broken nails had polished and rounded ends, indicating the extent of decking movement and the presence of sandy soil acting as an abrasive. Seven of the nail fragments in the upper row represent center or middle sections of through-nails that were broken into three pieces. (M 137 176)

Figure 9.--The upper surface of the center stringer showing broken and polished toenails and the scalloped pattern of wear resulting from pounding of the nominal 2-inch decking against the stringer surface. Practically all of the preservative-impregnated surface wood had been worn away in this area. In an area of broken toenails such as this, the decking obviously was not attached in any substantial degree to the stringer.

(M 138 117)

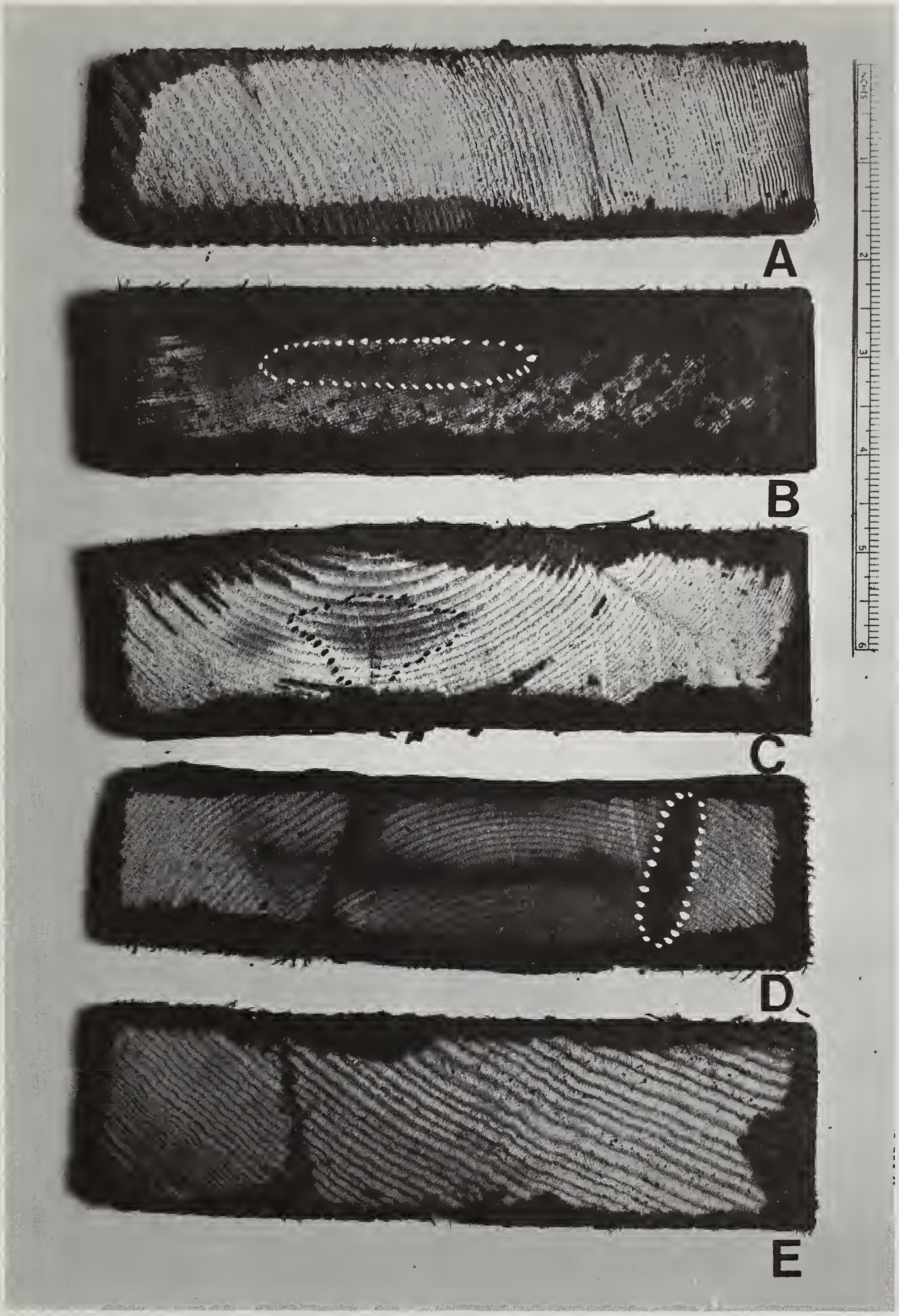

Figure 10.--Deck plank samples from the Panther Creek Bridge examined at the Forest Products Laboratory. A, heartwood plank poorly penetrated by the creosote pressure treatment; B, better preservative penetration than shown by most other samples, but typical decay is present in poorly treated interior wood, having gained entry through a hold-down bolt hole several inches from the cross section shown; C, incipient decay with slight iron stain of the interior, untreated wood; D, interior iron-stained wood reflecting the pattern of two through-nails and a tread plate hold-down bolt with typical decay present in alinement with one through-nail area; E, one of few samples with wood splitting associated with through-nailing. (M 137 174)

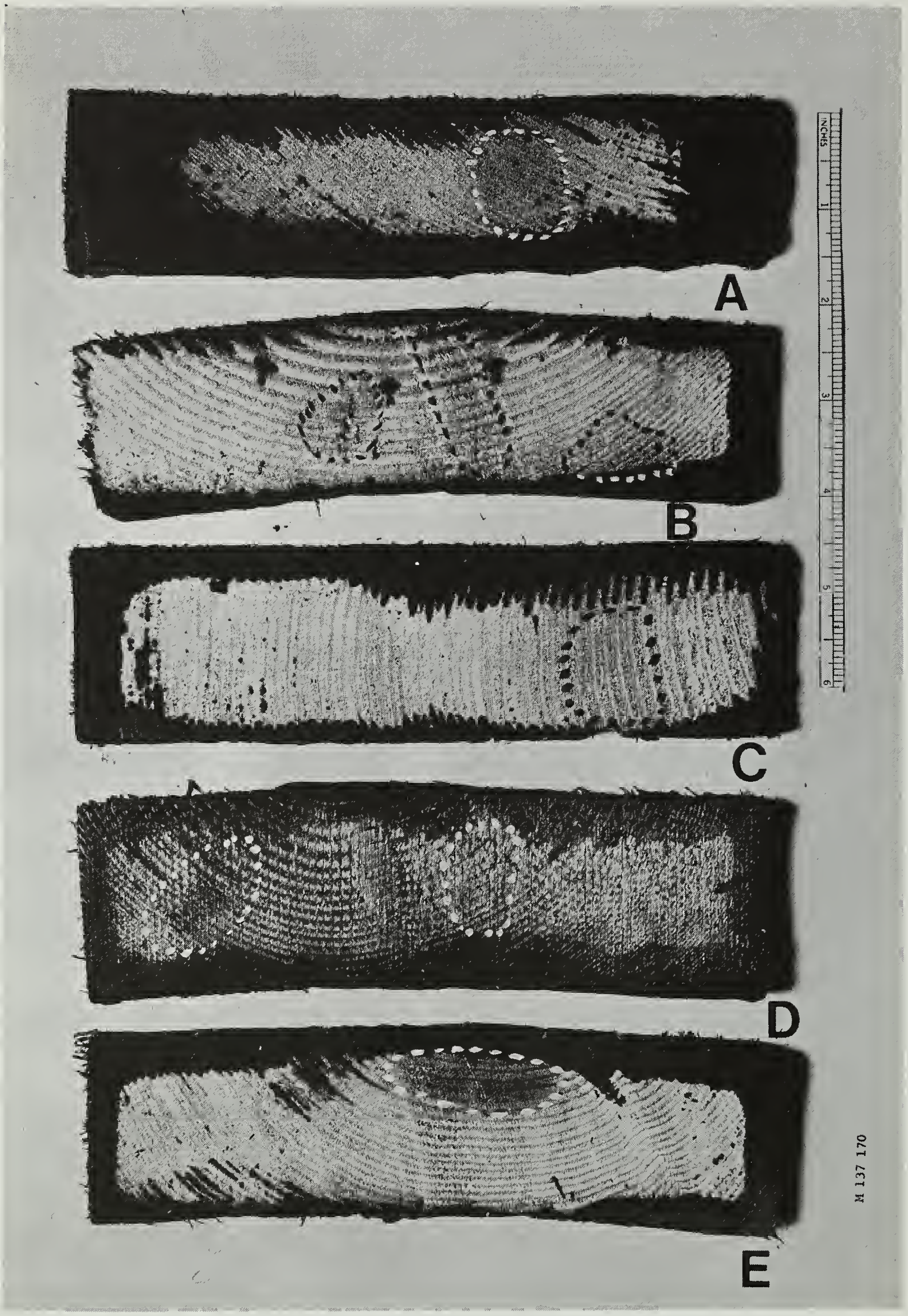

Figure 11.--All five decking samples show some incipient decay and some degree of iron stain. Both shrinkage and the resulting warp are evident by comparing the size and shape of the near normal shaped sample C, with the other four samples shown. From such an appraisal one can easily appreciate the nonuniform character of older nailed-laminated deck surfaces and spacing and the tendency of such decks to be severely loosened by repeated maximum loading after such shrinkage has occurred. B has a small area of typical or advanced decay. (M 137 170)

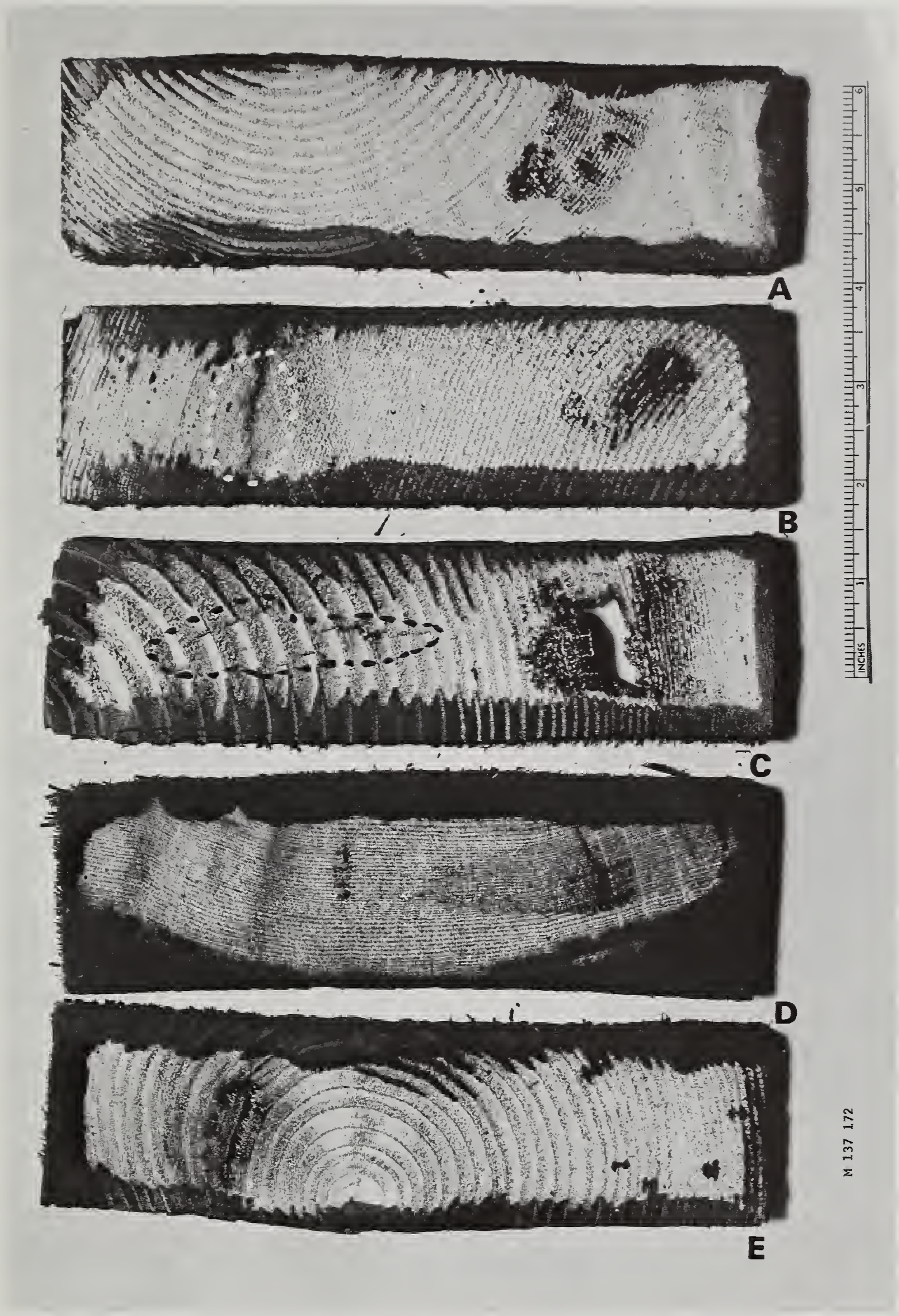

Figure 12.--Each of the five deck samples show at least one very definite area of advanced decay and samples B and C each show two areas of decay. Erratic preservative penetration is also apparent in this set of samples. The amount and severity of the decay shown here would account for a very severe loss of strength that is highly significant in view of the wide stringer spacings involved (long deck spans). Of equal importance is the fact that decayed deck elements do not occur in a truly random pattern of individual boards over the bridge length but instead tend to occur as groups of decayed boards alternating with groups of relatively sound boards having much less decay. (M 137 172)

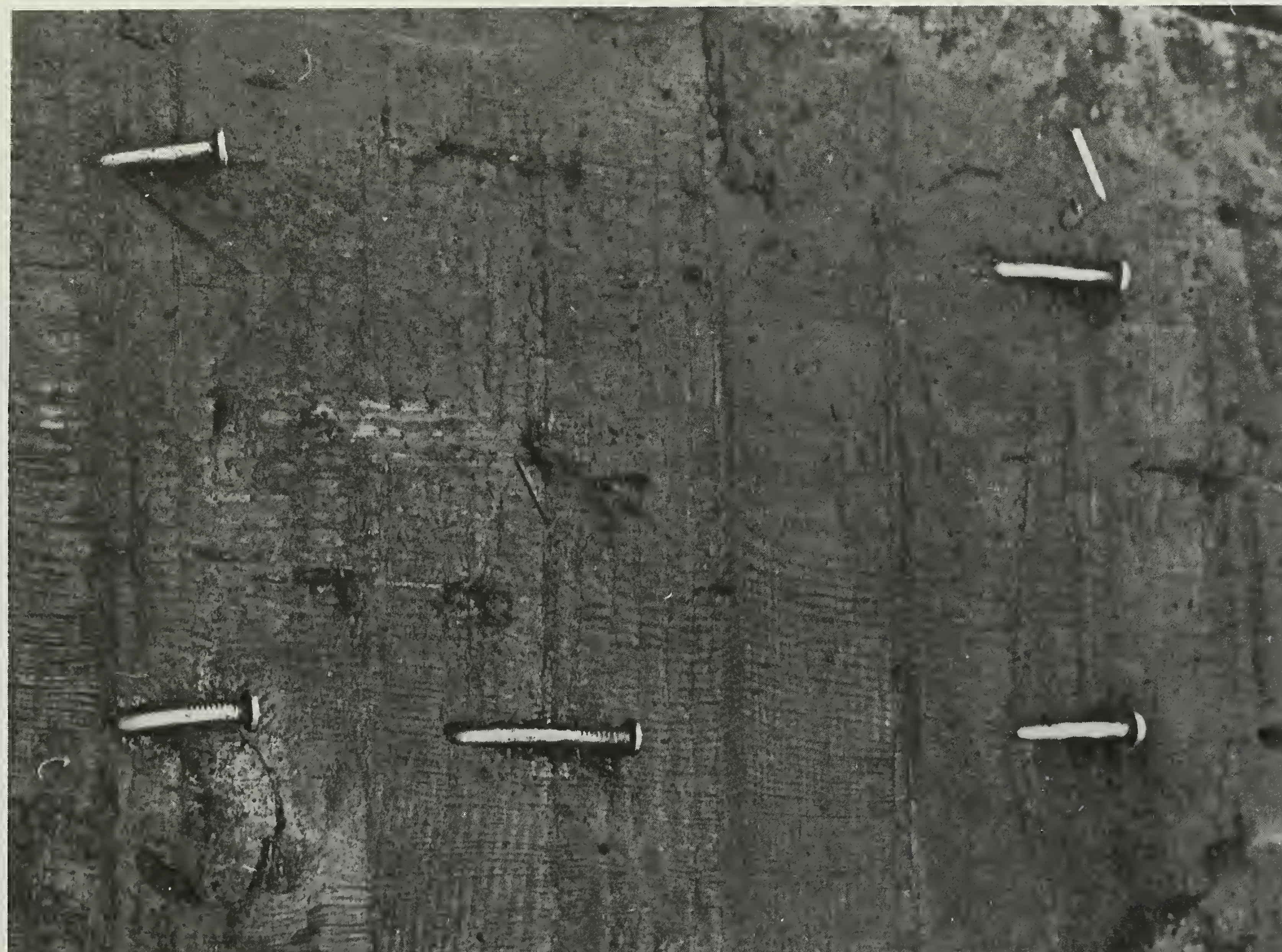

Figure 13.--This upper surface area of the center stringer shows inplace toenails which did not hold the decking in place on the stringer as evidenced from the wear pattern along the top of the stringer. This usually resulted from either toenail hole enlargement in the lower edge of the decking or actual splitting of the decking to release the decking to movement under traffic loading. (M 138 116)

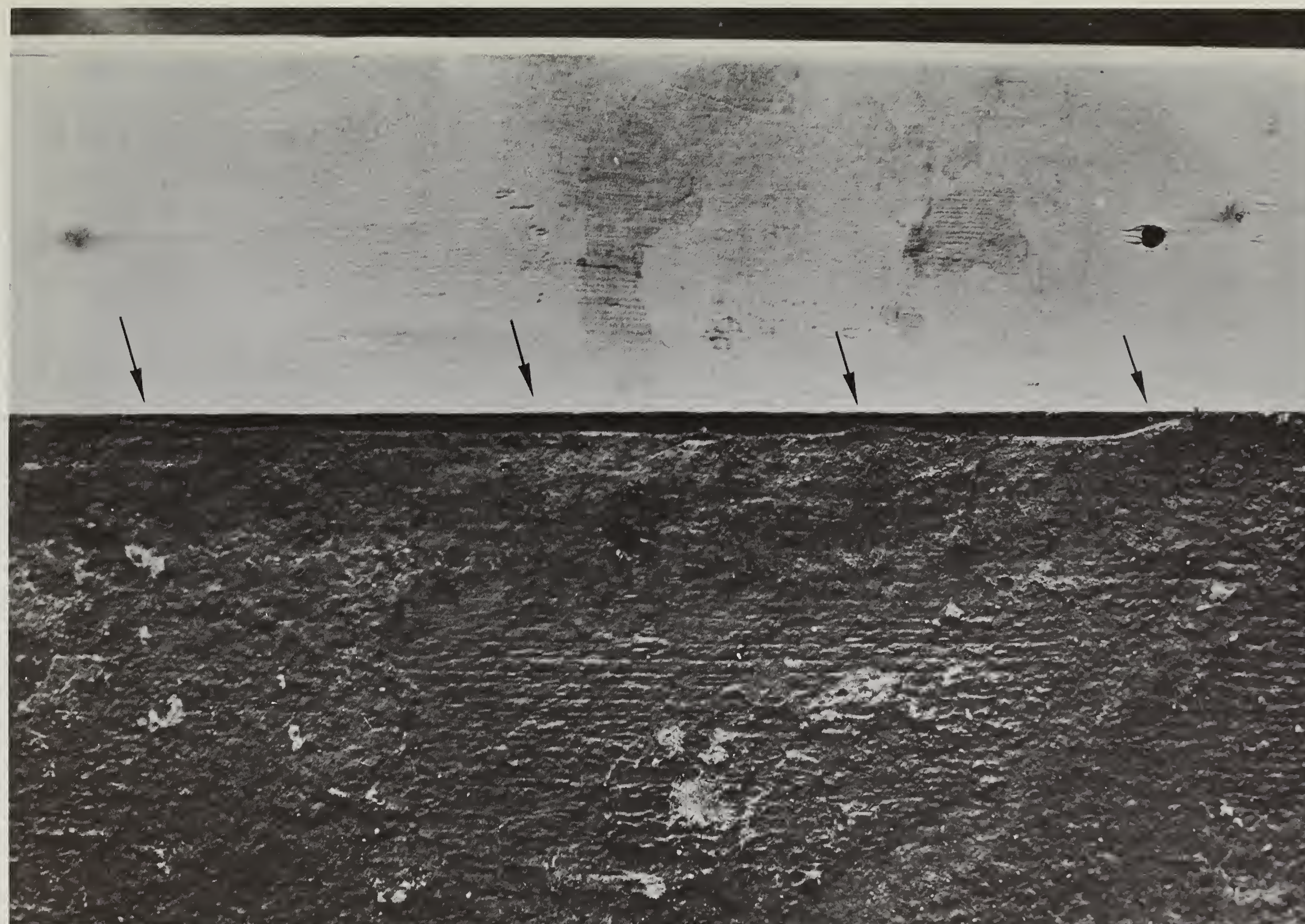

Figure 14.--The pattern of wear in a deck stringer member at a stringer contacting surface is shown by contrasting the worn area with a straight-edged, fresh 2- by 4-inch board held against the decking. (M 138 187)

Figure 15.--A section of the upper surface of an outer stringer showing the toenail holes and a large seasoning check. Both the toenail holes and the large checks expose untreated wood to rain seepage and consequent moisture buildup that constitutes a significant decay hazard.
(M 138 112)

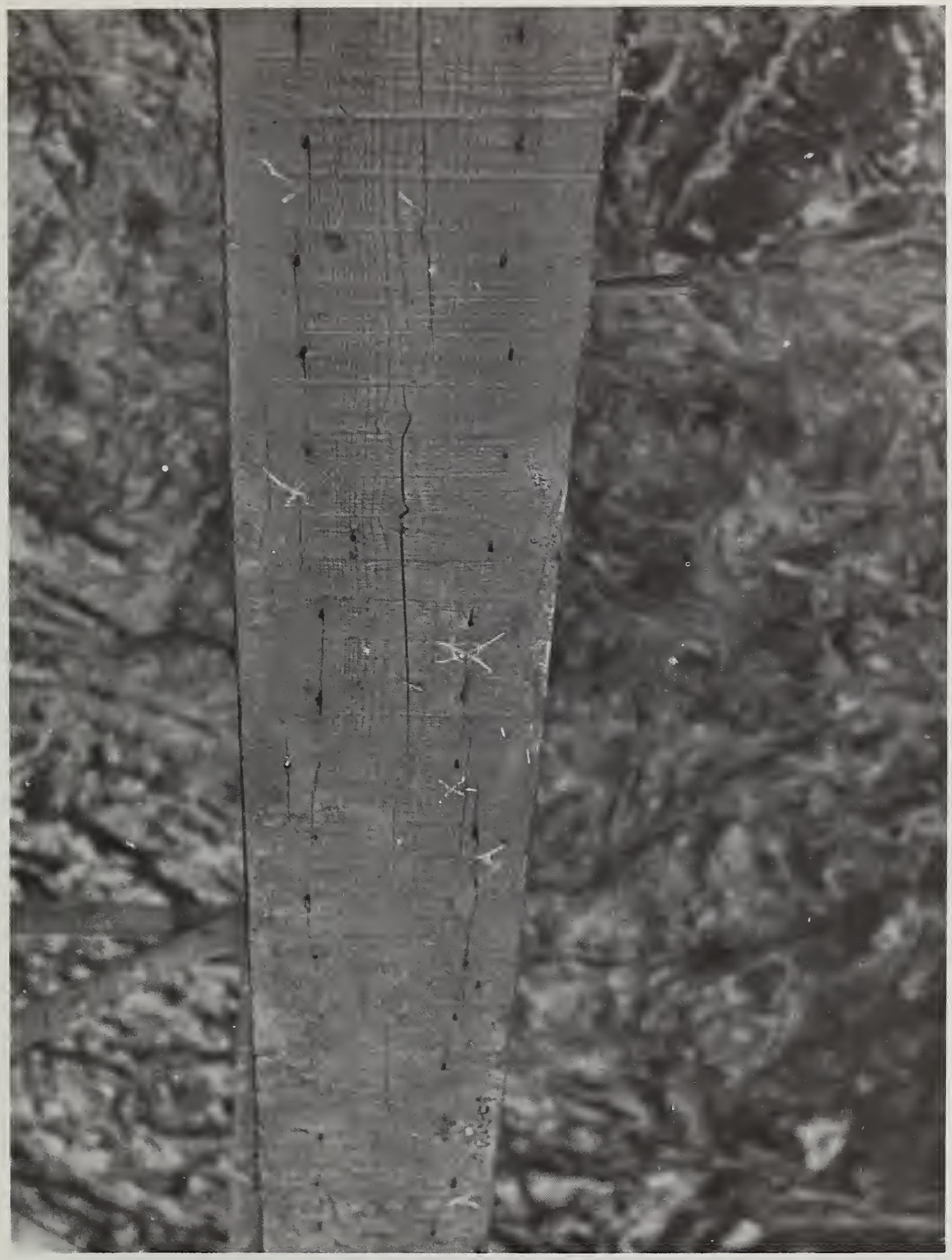

Figure 16.--The upper surface of a glued-laminated stringer after deck removal. Notice the short splits associated with many of the toenail holes and the larger checks associated with knots or slight defects along the centerline of the stringer. Such openings provide avenues for water entry and a resulting decay-hazard situation in the upper laminates of these stringers. (M 138 105)

Figure 17.--Glued-laminated panel being placed on the stringers by the forklift truck. (M 138 108)

Figure 18.--Steel dowels in place in predrilled holes in panel edges.
(M 138 115)

Figure 19.--Fastening glued-laminated deck panels to stringers with large ring-shank nails. (M 138 104)